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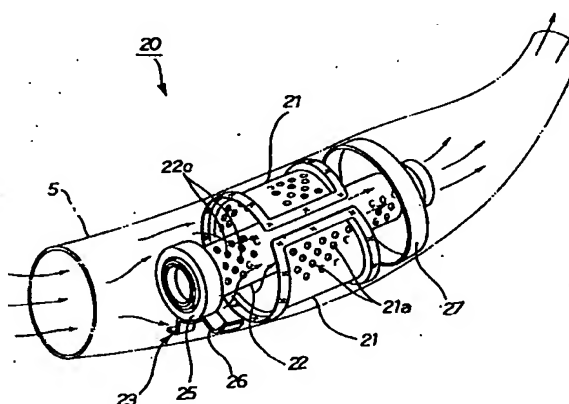
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(54) **EXHAUST EMISSION CONTROL DEVICE FOR INTERNAL COMBUSTION ENGINES**

(57) An exhaust emission control device wherein a thin steel plate (22) carrying catalytic metals is disposed substantially at the central portion of a cross section of an exhaust pipe (5) extending from an exhaust port (4) of an engine (3). Specifically, since the catalytic metals are disposed substantially at the central portion of the cross section of the exhaust pipe (5) which has a high exhaust gas temperature, an exhaust gas controlling action is sufficiently performed and moreover the production cost of the device can be reduced.

FIG. 5



EP 0 831 211 A1

## Description

### TECHNICAL FIELD

The present invention relates an improved exhaust purifying apparatus for purifying exhaust gas discharged from an internal combustion engine.

### BACKGROUND ART

Various types of exhaust purifying apparatuses for internal combustion engines are known today, among which are an "exhaust purifying apparatus for an internal combustion engine" disclosed in Japanese Patent Laid-open Publication No. HEI-3-85316 and an "exhaust purifying apparatus for a motor bicycle or the like" disclosed in Japanese Patent Laid-open Publication No. HEI-4-287821.

The exhaust purifying apparatus in the HEI-3-85316 publication is shown in Figs. 17 and 18, where an exhaust pipe 100 is coupled to an exhaust port of a small-size internal combustion engine mounted on a motor bicycle or the like, and a internal pipe 101 made of a porous sheet is disposed within the exhaust pipe 100 and extending along the inner surface of the pipe 100, with catalyst-bearing layers 102 attached to the inner and outer surfaces of the porous internal pipe 101.

The exhaust purifying apparatus in the HEI-4-287821 publication is shown in Figs. 19 to 21, where an exhaust muffler (corresponding to the exhaust pipe) 110 is coupled to an exhaust port of a small-size internal combustion engine mounted on a motor bicycle or the like, and a catalyst pipe 111 is provided in the central region of the exhaust muffler 110 with a catalyst-bearing member 112 received within the pipe 111. The catalyst-bearing member 112 comprises a honeycomb having catalyst materials attached thereto.

As known in the art, in order to allow catalysts to perform their exhaust purifying function to a sufficient degree, it is generally necessary to activate the catalysts by heating them to a high temperature. But, with a small-size internal combustion engine, it is not easy to increase the exhaust gas temperature sufficiently to activate the catalysts, and hence some measure has to be taken to increase the catalyst temperature as high as possible. To this end, one must take into account the fact that the temperature of exhaust gas flowing in the exhaust pipe is higher in the central region (i.e., the central region as viewed in cross section) of the pipe and lower in the peripheral region or near the inner wall surface of the pipe remote from the central region.

However, because the catalyst-attached internal pipe 101 is disposed near and along the inner wall surface of the exhaust pipe 100, the exhaust purifying apparatus shown in Figs. 17 and 18 can not easily provide a sufficient purifying capability.

On the other hand, the exhaust purifying apparatus shown in Figs. 19 to 21 can easily perform a sufficient

purifying capability because the catalyst bearing member 112 is located in the central region of the exhaust muffler 110 and the relatively high exhaust temperature can keep the catalysts hot. But, the honeycomb catalyst bearing member 112 in the apparatus in Figs. 19 to 21 tends to cause a greater loss in the exhaust gas pressure than the porous internal pipe 101 in the apparatus of Figs. 17 and 18. An even greater pressure loss would result in the central region of the muffler 110 where the exhaust gas flows at a higher speed. The performance of the internal combustion engine would be adversely influenced by the pressure loss to a substantial degree; in particular, the pressure loss could be a significant adverse factor for low-power internal combustion engines such as those of motor cycles. Further, the arrangement that the honeycomb catalyst member 112 is received in the catalyst pipe 111 would require a considerable manufacturing cost as compared to the arrangement that the catalyst-attached internal pipe 101 is just received in the exhaust pipe 100.

### DISCLOSURE OF THE INVENTION

It is therefore an object of the present invention to provide an exhaust purifying device for an internal combustion engine which achieves a sufficient purifying function while minimizing an adverse effect on the performance of the engine and yet can be manufactured at low cost.

The present invention provides an exhaust purifying device for an internal combustion engine which is characterized in that a steel sheet member having inner and outer catalytic-metal-bearing surfaces is disposed substantially in the central region of an exhaust port extending from an exhaust port of the internal combustion engine. Thus, the catalytic metal is placed in the region of the exhaust pipe where the temperature of the exhaust gas from the engine is relatively high. The high-temperature exhaust gas effectively activates the catalytic metal on the steel sheet member to thereby allow the catalytic metal to perform its exhaust purifying function to a sufficient degree. The steel sheet member is preferably in the form of a hollow cylinder extending in the axial direction of the exhaust port so that a pressure loss in the exhaust gas flowing through the steel sheet member can be reduced. Preferably, the cylinder is made of a porous steel sheet and closed at its upstream end. In this case, the exhaust gas is directed to pass through small openings formed through the wall thickness of the cylinder, during which time the exhaust gas contacts the catalytic metal on the inner and outer catalytic-metal-bearing surfaces. Thus, the exhaust is acted on by the catalytic metal in a greater area of the surfaces and accordingly can provide an enhanced exhaust purifying capability.

According to another aspect of the present invention, a hollow cylinder is provided and supported substantially in the central region of the exhaust pipe, and

the hollow cylinder is made of a steel sheet having inner and outer catalytic-metal-bearing surfaces. Also, a partition plate is provided within the exhaust pipe to block passage of the exhaust gas between the cylinder and the exhaust pipe. The partition plate functions to suppress the pulsating motion of the exhaust gas caused by the engine, so as to provide a generally smooth steady flow of the exhaust gas. Owing to the provision of such a partition plate, the purifying capability of the exhaust purifying apparatus does not significantly vary and hence can be enhanced effectively. Further, because the steel cylinder is supported via the partition plate suppressing the pulsating motion of the exhaust gas, no separate support is required.

The steel cylinder is mounted in such a manner that the cylinder is free to axially expand or contract relative to the exhaust pipe, and this feature advantageously accommodates a difference in amounts of axial thermal expansion between the steel cylinder and exhaust pipe.

According to another aspect of the present invention, a first catalytic-metal-bearing member is provided within the exhaust pipe along an inner wall surface of said pipe and a second catalytic-metal-bearing member is provided substantially in the central region of the first catalytic-metal-bearing member. Because the catalytic-metal-bearing members are provided near the inner wall surface of and in the central region of the exhaust pipe, the exhaust purifying function can be further enhanced without adversely affecting the performance of the internal combustion engine.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side elevational view showing a motor cycle on which is mounted an exhaust purifying apparatus for an internal combustion engine according to a first embodiment of the present invention,

Fig. 2 is a side view showing an embodiment of an exhaust pipe employed in the apparatus of Fig. 1 and constructed in accordance with the present invention,

Fig. 3 is a sectional view taken along the line A - A of Fig. 2, showing an upstream exhaust purifier shown in Fig. 2,

Fig. 4 is a sectional view taken along the line B - B of Fig. 3,

Fig. 5 is a perspective view showing an embodiment of a downstream exhaust purifier shown in Fig. 2,

Fig. 6 is a sectional view taken along the line C - C of Fig. 2,

Fig. 7 is a sectional view taken along the line D - D of Fig. 6,

Fig. 8 is a sectional view taken along the line E - E of Fig. 6,

Figs. 9A to 9E are views showing how a second catalytic-metal-bearing member of the downstream

exhaust purifier of Fig. 5 is assembled,

Figs. 10A to 10D are views showing modifications of the second catalytic-metal-bearing member,

Figs. 11A to 11H are views showing modifications of a support structure for the second catalytic-metal-bearing member,

Fig. 12 is a perspective view showing another embodiment of the downstream exhaust purifier,

Fig. 13 is a sectional view taken along the line F - F of Fig. 12,

Fig. 14 is a view showing a modification of the downstream exhaust purifier of Fig. 12,

Fig. 15 is a sectional view taken along the line G - G of Fig. 14,

Figs. 16A to 16E are views showing still another embodiment of the exhaust purifier apparatus,

Fig. 17 is a cross-sectional view of an exhaust pipe in a prior art exhaust purifying apparatus,

Fig. 18 is a side view, partly in vertical section, of the exhaust pipe of Fig. 17,

Fig. 19 is a plan view of an exhaust muffler in another prior art exhaust purifying apparatus,

Fig. 20 is a perspective view, partly in vertical section, of the exhaust purifying apparatus of Fig. 19, and

Fig. 21 is a vertical sectional view of a catalyst pipe and peripheral components in the exhaust purifying apparatus of Fig. 19.

#### BEST MODE FOR CARRYING OUT THE INVENTION

Fig. 1 is a side elevational view showing a motor cycle 1 on which is mounted an exhaust purifying apparatus for an internal combustion engine according to a first embodiment of the present invention. As shown, the motor cycle 1 includes a two-cycle internal combustion engine 3 provided near the central part of a vehicle body 2, and an exhaust pipe 5 connected to an exhaust port 4 of the engine 3. The rear end portion of the exhaust pipe 5 is coupled to a muffler 6.

Fig. 2 shows details of the exhaust pipe 5, which is formed of a thin steel sheet and has a circular sectional shape. The exhaust pipe 5 having an upstream end portion 5a connected by flange coupling to the engine exhaust port 4 of Fig. 1 and having a downstream end portion 5b connected by flange coupling to the muffler 6 of Fig. 1 (the words "upstream" and "downstream" are used herein in terms of the flow of exhaust gas from the engine exhaust port 4). Upstream and downstream exhaust purifiers 10 and 20 are provided within the exhaust pipe 5; in other words, the former is a front-stage exhaust purifier and the latter is a rear-stage exhaust purifier. The portion of the exhaust pipe 5 in which the downstream exhaust purifier 20 is disposed is greater in diameter than the other portions of the pipe 5.

Fig. 3 shows a detailed structure of the upstream exhaust purifier 10 in a sectional view taken along the line A - A of Fig. 2. The upstream exhaust purifier 10

includes an internal pipe 11 having numerous small openings 11c formed through the wall thickness thereof, which is disposed within the exhaust pipe 5 and in the form of a hollow cylinder made of a thin, porous steel sheet and extending along the inner wall surface of the exhaust pipe 5. The internal pipe 11 has one or upstream end portion 11a fixed by welding to the inner wall surface of the exhaust pipe 5 and the other or downstream end portion 11b supported by a support member 13 in such a manner that the downstream end portion 11b is free to axially move (expand or contract) relative to the exhaust pipe 5 so as to accommodate a difference in amounts of axial thermal expansion between the two pipes 5 and 11.

The inner wall surface of the internal pipe 11 has a layer of catalytic metal, such as platinum or rhodium, which is formed by, for example, applying a solution of the catalytic metal onto the surface. A clearance 5c is formed between the intermediate portion of the exhaust pipe 5 and the internal pipe 11.

As shown in Fig. 4, the exhaust pipe 5 comprises a pair of upper and lower hollow cylinder halves each having a semicircular sectional shape, which are welded together into a hollow cylinder with the internal pipe 11 received therein.

The support member 13 comprises a corrugated sheet that is wound around the outer periphery of the internal pipe 11 with its parallel ridges and grooves extending in the axial direction of the exhaust pipe 5 (i.e., the ridges and grooves alternating along the periphery of the pipe 11). Overlapping surfaces of the thus-wound corrugated sheet are secured together by spot-welding. By means of such a corrugated structure, the support member 13 can resiliently deform relative to the internal pipe 11 in the radial direction thereof to allow the downstream end portion 11a of the internal pipe 11 to axially slide along the support member 12, to thereby accommodate a difference in amounts of axial thermal expansion between the exhaust pipe 5 and internal pipe 11 due to the temperature of the exhaust gas. Note that the above-mentioned corrugated sheet is just illustrative and the support member 13 may be implemented in any other suitable manner, such as by a stainless steel wire knitted into a ring disposed around the outer periphery of the internal pipe 11.

Protecting members 14 are in the form of a pair of hollow cylinder halves (each having a substantially semicircular sectional shape) are bolted to nuts 15 welded to the outer periphery of the exhaust pipe 5, so as to together form a substantially cylindrical cover for the exhaust pipe 5 that are heated by the exhaust gas flowing therethrough.

Fig. 5 shows the downstream exhaust purifier 20 of Fig. 2, which includes a first catalytic-metal-bearing member 18 provided within the exhaust pipe 5 near the inner wall surface of the pipe 5. The first catalytic-metal-bearing member 18 comprises a pair of hollow cylinder halves 21 each having a semicircular sectional shape

so as to together form a hollow cylinder within the exhaust pipe 5 as shown in Fig. 5. A second catalytic-metal-bearing member 22, which is in the form of a straight hollow cylinder smaller in diameter than the first catalytic-metal-bearing member 18, is provided substantially in a central region (i.e., central region as viewed in cross section) of the bearing member (and hence substantially in a central region of the exhaust pipe 5). It can be said that the exhaust pipe 5 and first and second catalytic-metal-bearing members 18 and 22 are mounted concentrically. The first and second catalytic-metal-bearing members 18 and 22 both extend in the axial direction of the exhaust pipe 5.

Each of the first and second catalytic-metal-bearing members 18 and 22 is made of a thin, porous steel sheet to have numerous small openings 21a, 22c formed through the wall thickness thereof. A layer of catalytic metal, such as platinum or rhodium, is formed on the wall surfaces of the first and second catalytic-metal-bearing members 18 and 22 by, for example, applying a solution of the catalytic metal onto the surfaces. A clearance is formed between the exhaust pipe 5 and the hollow cylinder halves 21 of the first catalytic-metal-bearing member 18.

As shown in Fig. 6, a support structure 23 is provided, at one or upstream end portion (left end portion in the figure) 22a of the second catalytic-metal-bearing member 22, to support the end portion 22a in such a manner that the end portion 22a is free to axially move (expand or contract) relative to the exhaust pipe 5. The support structure 23 includes a cushion member 24 wound around the upstream end portion 22a of the second catalytic-metal-bearing member 22, an annular holder 25 receiving and holding the cushion member 24 in place, and a bracket 26 that secures the annular holder 25 with the cushion member 24 to the exhaust pipe 5. Because of the cushion member 24, the support structure 23 accommodates a difference in amounts of axial thermal expansion between the exhaust pipe 5 and the second catalytic-metal-bearing member 22 by allowing the upstream end portion 22a to axially move relative to the exhaust pipe 5. Further, a cap 28 is provided within the second catalytic-metal-bearing member 22 to close the upstream end portion 22a of the member 22.

A partition plate 27 is provided, at the downstream end portion (right end portion in the figure) of the second catalytic-metal-bearing member 22, to support that end and block passage of the exhaust gas between the second catalytic-metal-bearing member 22 and the exhaust pipe 5. The partition plate 27, which is a dish-shaped end plate made of a thin steel plate, has a flange along the entire outer periphery thereof and is fixed in place by the flange being plug-welded to the inner wall surface of the exhaust pipe 5. The other or downstream end portion 22b is threaded through a central through-hole 27b and fixed by welding to the entire edge of the plate 27 defining the through-hole 27b.

As shown in Fig. 7 which is a sectional view taken along the line D - D of Fig. 6, the cushion member 24 comprises a corrugated sheet that is wound around the outer periphery of the second catalytic-metal-bearing member 22 with its parallel ridges and grooves extending in the axial direction of the exhaust pipe 5 (i.e., the ridges and grooves alternating along the outer periphery of the member 24). The thus-wound corrugated sheet is fixed around the second catalytic-metal-bearing member 22 by spot-welding its overlapping surfaces. Owing to such a corrugated structure, the cushion member 24 can resiliently deform relative to the member 22 in the radial direction thereof, so as to accommodate a difference in amounts of axial thermal expansion between the exhaust pipe 5 and second catalytic-metal-bearing member 22.

As shown in Fig. 8 which is a sectional view taken along the line E - E of Fig. 6, each of the hollow cylinder halves 21 of the first catalytic-metal-bearing member 18 is spot-welded at its opposite edges to the inner wall surface of the exhaust pipe 5.

The following paragraphs describe how the above-mentioned second catalytic-metal-bearing member 22 is assembled, with reference to Figs. 6 and 9A - 9E.

First, the cap 28 is fit into the upstream end portion 22a of the second catalytic-metal-bearing member 22 as shown in Fig. 9A, and the outer peripheral edge of the cap 28 and the inner wall surface of the member 22 are fixed together by spot welding in order to close the upstream end portion 22a as shown in Fig. 9B. Then, as shown in Fig. 9C, the downstream end portion 22b of the second catalytic-metal-bearing member 22 is threaded through the central through-hole 27b of the partition plate 27 and welded to the edge defining the hole 27b.

After that, the annular holder 25 receiving the cushion member 25 (Fig. 6) is threaded on the upstream end portion 22a of the second catalytic-metal-bearing member 22 as shown in Fig. 9D, and the second catalytic-metal-bearing member 22 is assembled into a predetermined condition as shown in Fig. 9E. The second catalytic-metal-bearing member 22 assembled as shown in Fig. 9E is then positioned in the lower half of the exhaust pipe 5 as shown in Fig. 6, and a part of the outer surface of the annular holder 25 is welded to the bracket 26 previously fixed to the exhaust pipe 5. Finally, the upper hollow cylinder half of the exhaust pipe 5 is placed edge to edge on the lower hollow cylinder half, then the upper and lower hollow cylinder halves are welded together, and then the flange 27a of the partition plate 27 is plug-welded to the inner wall surface of the exhaust pipe 5. This completes the required assembly of the second catalytic-metal-bearing member 22.

Next, with reference to Figs. 2 and 6, a description will be given as to how the upstream and downstream exhaust purifiers 10 and 20 behave.

As shown in Fig. 2, the exhaust gas from the internal combustion engine is introduced into the exhaust

pipe 5 via its upstream end portion 5a. As the introduced exhaust gas passes through the upstream exhaust purifier 10, the exhaust gas contacts the catalytic metal layers on the inner and outer surfaces of the internal pipe 11 and is effectively purified through its chemical reaction with the catalytic metal. The exhaust gas thus purified by the upstream exhaust purifier 10 is then directed toward the downstream exhaust purifier 20.

As shown in Fig. 6, the exhaust gas initially purified by the upstream exhaust purifier 10 is prevented from flowing into the second catalytic-metal-bearing member 22 through its upstream end portion 22a because the end portion 22a is closed by the cap 28.

A portion of the exhaust pipe 5 in which the downstream exhaust purifier 20 is disposed is greater in diameter than the other portions of the pipe 5 as noted earlier, and this greater-diameter portion is partitioned off by the partition plate 27 so that an expanding chamber 29 is formed in the greater-diameter portion upstream of the plate 27. The expanding chamber 29 functions to suppress the pulsating motion of the exhaust gas caused by the engine 3, so as to provide a generally smooth steady flow of the exhaust gas. This allows the exhaust gas to flow as indicated by black arrows, and a portion of the exhaust gas flowing near and along the inner wall surface of the exhaust pipe 5 comes into contact with the catalytic metal layers on the inner and outer surfaces of the first catalytic-metal-bearing member 18 to be purified through its chemical reaction with the catalytic metal.

In the meantime, another portion of the exhaust gas flows into the second catalytic-metal-bearing member 22 via the numerous small openings 22c, flows through the member 22 and then is discharged through the downstream end portion of the exhaust pipe 5 into the atmosphere. As the exhaust gas flows in the second catalytic-metal-bearing member 22, it comes into contact with the catalytic metal layer surfaces on the member 22 to be purified through its chemical reaction with the catalytic metal.

When passing through the numerous small openings 22c formed in the second catalytic-metal-bearing member 22, the exhaust gas contacts the catalytic metal layers on the outer and inner wall surfaces of the member 22. Therefore, the exhaust gas can contact a great area of the catalytic metal layers, and thus the catalytic metal can perform its exhaust purifying function to a sufficient degree.

As previously discussed in relation to the prior art apparatuses, it is necessary to activate the catalyst metal by heating in order to allow the catalyst metal to perform its exhaust purifying function to a sufficient degree, and the temperature of the exhaust gas flowing in the exhaust pipe is higher in the central region of the pipe and lower near the inner wall surface of the pipe. According to the embodiment of the present invention, even a relatively hot portion of the exhaust gas flowing

in the central region of the exhaust pipe 5 is caused to flow in the downstream exhaust purifier 20 in contact with the catalytic metal layer, the catalytic metal can be sufficiently activated by being heated by the high-temperature exhaust gas and thus perform its exhaust purifying function to a sufficient degree. In addition, the second catalytic-metal-bearing member 22, in the form of a hollow cylinder having a porous wall, effectively reduces a pressure loss of the exhaust gas flowing through the member 22, so that the engine performance will not be significantly influenced by the pressure loss.

In the above-mentioned manner, the exhaust gas from the internal combustion engine 3 can be purified efficiently by contacting the catalytic metal layers on the first and second catalytic-metal-bearing members 18 and 22. Besides, because the exhaust gas is allowed to flow in a generally smooth steady current, the purifying capability of the downstream exhaust purifier 20 does not significantly vary, which would result in uniform and efficient exhaust purification.

Due to heat of the reaction, the second catalytic-metal-bearing member 22 becomes much hotter than the exhaust pipe 5. While the downstream end portion 22b is fixed to the exhaust pipe 5 via the partition plate 27, the upstream end portion 22a is movably mounted via the support structure 23 on the fixed bracket 26 of the exhaust pipe 5. Thus, when a difference in amounts of axial thermal expansion occurs between the exhaust pipe 5 and the member 22, the upstream end-portion 22a is allowed to move relative to the bracket 26, in the upstream direction as indicated by a white arrow, to thereby accommodate the difference in axial expansion. Specifically, the difference in axial expansion between the exhaust pipe 5 and the second catalytic-metal-bearing member 22 is accommodated by the resilient deformation of the cushion member 24.

The second catalytic-metal-bearing member 22 has been described above as being closed at the upstream end portion 22a by the straight vertical cap 28, but the closing structure of the upstream end portion 22a may be modified in various ways as shown in Figs. 10A to 10D.

In the modification of Fig. 10A, the upstream end portion 22a of the second catalytic-metal-bearing member 22 is closed by a porous cap 31 that projects upstream in a dome-like shape. The cap 31 may be made by pressing a porous sheet material. In Fig. 10B, another modified cap 32 is formed by squeezing or pressing the upstream end portion 22a flat.

In Fig. 10C, a modified cap 33 comprises a plurality of porous blades that are attached spirally (i.e., in the shape of a pinwheel) to the upstream end portion 22a of the second catalytic-metal-bearing member 22. This spiral cap 33 functions to increase the flowing resistance of the exhaust gas. Finally, in the modification of Fig. 10D, the upstream end portion 22a of the second catalytic-metal-bearing member 22 is closed by a cap 34 made of a flat porous plate. In stead of providing the

flat porous cap 34, the upstream end portion 22a may itself be folded toward its center along the entire peripheral edge thereof to form an integral cap.

Each of the caps 31, 32, 33 and 34 functions in the same way as in the above-described first embodiment, and additionally, the pressure loss resulting from the provision of the cap is substantially reduced as compared to the first embodiment by virtue of its porous nature.

While the second catalytic-metal-bearing member 22 has been described above being supported at one end portion supported movably relative to the exhaust pipe 5 and fixed at the other end portion to the exhaust pipe 5, the mounting mechanism of the member 22 may be modified in various ways as shown in Figs. 11A to 11H. In each of these figures, the exhaust gas flows rightward as indicated by black arrows and the one or upstream end portion 22a of the second catalytic-metal-bearing member 22 is allowed to move leftward as indicated by a white arrow.

In the modification of Fig. 11A, the upstream end portion 22a projects upstream beyond the support structure 23 and is closed by a flat cap 28. In the modification of Fig. 11B, the upstream end of the support structure 23 is closed by a cap 36. Between the upstream end portion 22a and the cap 36, there is provided a clearance  $S_1$  having an axial length greater than an expected maximum amount of axial thermal expansion of the second catalytic-metal-bearing member 22. In this case, no cap separate from the cap 36 needs to be attached to the upstream end portion 22a of the catalytic-metal-bearing member 22. In the modification of Fig. 11C, the annular holder member 25 of the support structure 23 is greater in axial length than the bracket 26 and projects upstream beyond the bracket 26.

Further, in Fig. 11D, the catalytic-metal-bearing member 22 is supported only at the downstream end portion 22b by a supporting structure 37 in a so-called "cantilever" fashion. The support structure 37 includes a cushion member 38 that supports the downstream end portion 22b in such a manner that the end portion 22a is free to axially move (expand and contract) relative to the exhaust pipe 5, a holder member 39 receiving and holding the cushion member 38, and a partition plate 27 fixing the holder member 39 to the exhaust pipe 5. A clearance  $S_2$  is provided between the downstream end portion 22b and a flange 39a of the holder member 39 so that movement of the downstream end portion 22b relative to the exhaust pipe 5 is limited within the bound of the clearance  $S_2$ . In the modification of Fig. 11E, cushion and holder members 38 and 39 are smaller in axial length than those of Fig. 11D.

In the modification of Fig. 11F, the catalytic-metal-bearing member 22 is fixed at the upstream end portion 22a to the exhaust pipe 5 via a bracket 41 and supported at the downstream end 22b via a support structure 42 for axial movement relative to the exhaust pipe 5. The support structure 42 includes a cushion member

43 that supports the downstream end portion 22b in such a manner that the end portion 22b is free to axially move (expand or contract) relative to the exhaust pipe 5, a holder member 44 receiving and holding the cushion member 43 in place, and a partition plate 27 fixing the holder member 44 to the exhaust pipe 5. The downstream end portion 22b projects downstream beyond the support structure 42.

Further, the modification of Fig. 11G is similar to that of Fig. 11F, except that the upstream end portion 22a is closed by a cap 45 having a locking projection to engage or disengage the end portion by a user's snap action. The modification of Fig. 11H employs a pair of front and rear cushion members 48 different from the above-mentioned cushion members 24, 38, 43, each of which comprises a stainless steel wire knitted into a ring around the outer periphery of the downstream end portion 22b. Support structure 46 includes a seat 47 wound around the downstream end portion 22b, the front and rear cushion members 48 disposed upstream and downstream of the seat 47, respectively, for supporting the downstream end portion 22b in such a manner that the end portion 22b is axially movable relative to the exhaust pipe 5, a holder member 49 receiving and holding the cushion members 48, and a partition plate 27 fixing the holder member 49 to the exhaust pipe 5.

The following paragraphs describe a second embodiment of the downstream exhaust purifier with reference to Figs. 12 and 13.

In the downstream exhaust purifier 50 of Fig. 12, a first catalytic-metal-bearing member 51 is provided near and along the inner wall surface of the exhaust pipe, and a second catalytic-metal-bearing member 52 is provided substantially in a central region within the first catalytic-metal-bearing member 51 (and hence in a central region of the exhaust pipe 5). The first and second catalytic-metal-bearing members 51 and 52 extend in the axial direction of the exhaust pipe 5.

The first catalytic-metal-bearing member 51 is a hollow cylinder that is made of a porous steel sheet (having numerous small openings 51c formed through the wall thickness thereof) and has outwardly-widening conical portions 51a at the axially opposite ends thereof, and at least one of the conical portions 51a is fixed by welding to the inner wall surface of the exhaust pipe 5. The second catalytic-metal-bearing member 52 is a flat porous steel sheet (having numerous small openings 52c formed through the wall thickness thereof) and welded at at least one of its longitudinal edges to the inner wall surface of the first catalytic-metal-bearing member 51. On the wall surfaces of the first and second catalytic-metal-bearing members 51 and 52, a layer of catalytic metal, such as platinum or rhodium, is formed by, for example, applying a solution of the catalytic metal onto the surfaces. Fig. 13 is a sectional view taken along the line F - F of Fig. 12, showing the flat second catalytic-metal-bearing member 52 in an upright position within the first catalytic-metal-bearing

member 51.

The following paragraphs describe how the downstream exhaust purifier 50 of Fig. 12 operates, with reference to Fig. 12.

The exhaust gas from the internal combustion engine flows as denoted by arrows. More specifically, a portion of the exhaust gas flowing near and along the inner wall surface of the exhaust pipe 5 is caused to pass through the numerous small openings 51c formed in the wall of the catalytic-metal-bearing member 51, and another portion of the exhaust gas flowing in a generally central region of the exhaust pipe 5 is caused to pass through the numerous small openings 52a formed in the second second catalytic-metal-bearing member 52. Thus, the exhaust gas contacts the catalytic metal layers on the inner and outer surfaces of the first and second catalytic-metal-bearing members 51 and 52 and is effectively purified through its chemical reaction with the catalytic metal.

When passing through the numerous small openings 52a formed in the second catalytic-metal-bearing member 52, the exhaust gas contacts the catalytic metal layers on the outer and inner wall surfaces of the member 52. Therefore, the exhaust gas is brought into contact with a great area of the catalytic metal layers, and the catalytic metal can perform its exhaust purifying function to a sufficient degree.

Further, because the second catalytic-metal-bearing member 52 contacts the relatively hot portion of the exhaust gas flowing through the central region in the exhaust pipe 5, the catalytic metal can be heated to be sufficiently activated and therefore can perform its exhaust purifying function to a sufficient degree. In addition, because the second catalytic-metal-bearing member 52 is just in the form of a flat plate, a pressure loss of the exhaust gas flowing in the member 52 can be reduced even further than in the above-described first embodiment of the downstream exhaust purifier.

The downstream exhaust purifier 50 of Fig. 12 may be modified in such a manner as shown in Figs. 14 and 15. Namely, in the modification, the first catalytic-metal-bearing member 51 is in the form of a hollow cylinder having a generally C-shape in section with a part (bottom part in the example of Fig. 14) cut away along the entire length thereof. As shown in Fig. 15, the first catalytic-metal-bearing member 51 in the form of the partly-cut-away hollow cylinder has a pair of flanges 51b integrally formed with the opposed longitudinal edges, which are in contact with the inner wall surface of the exhaust pipe 5. In this example, one longitudinal edge portion extends, through the opening between the opposed longitudinal edges of the second catalytic-metal-bearing member 52, into contact with the wall surface of the exhaust pipe 5.

Figs. 16A to 16E schematically shows several other embodiments of the exhaust purifying apparatus.

The exhaust purifying apparatus 61 shown in Fig. 16A, which comprises a pair of upstream (front-stage)



and downstream (rear-stage) exhaust purifiers disposed within an exhaust pipe 5, is characterized by the provision of a control valve (e.g., butterfly valve) 62 between the upstream and downstream exhaust purifiers. The upstream exhaust purifier is constructed in the same manner as the upstream exhaust purifier 10 of Fig. 3, and the downstream exhaust purifier is constructed in the same manner as the downstream exhaust purifier 50 of Fig. 12.

The exhaust purifying apparatus 63 shown in Fig. 16B comprises three exhaust purifiers disposed in succession within an exhaust pipe 5. The upstream (front-stage) exhaust purifier is constructed in the same manner as the upstream exhaust purifier 10 of Fig. 3, the central (intermediate-stage) exhaust purifier is constructed in the same manner as the downstream exhaust purifier 50 of Fig. 12, and the downstream (rear-stage) exhaust purifier is an exhaust discharging conduit 64 partly extending out of the exhaust pipe 5. The exhaust discharging conduit 64 is made of a porous steel sheet, and a layer of catalytic metal, such as platinum or rhodium, is formed on the inner and outer wall surfaces of the conduit 64 by, for example, applying a solution of the catalytic metal onto the surfaces.

The exhaust purifying apparatus 65 shown in Fig. 16C comprises a catalytic-metal-bearing member 66 that is disposed in a central region and extends in the axial direction of an exhaust pipe 5. The catalytic-metal-bearing member 66 is made of a flat, porous steel sheet, and a layer of catalytic metal, such as platinum or rhodium, is formed on the opposite wall surfaces of the member 66 by, for example, applying a solution of the catalytic metal onto the surfaces. The exhaust purifying apparatus 67 shown in Fig. 16D is a modification of the exhaust purifying apparatus 65 of Fig. 16C, which is characterized in that the catalytic-metal-bearing member 66 is made of a corrugated porous steel sheet rather than the flat, porous steel sheet of Fig. 16C.

The exhaust purifying apparatus 68 shown in Fig. 16E comprises a catalytic-metal-bearing member 69 in the form of a hollow semicylinder, which extends in the axial direction of an exhaust pipe 5 and is closed at opposite ends. The semicylindrical catalytic-metal-bearing member 69 has a hollow space 69a, opening toward the inner wall surface of the exhaust pipe 5, between the opposed longitudinal edges thereof. The catalytic-metal-bearing member 69 is made of a porous steel sheet, and a layer of catalytic metal, such as platinum or rhodium, is formed on the inner and outer wall surfaces of the member 69 by, for example, applying a solution of the catalytic metal onto the surfaces.

Note that any of the catalytic-metal-bearing members 66 and 69 shown in Figs. 16C, 16D and 16E may be employed in the plural-stage exhaust purifiers of Figs. 16A and 16B provided within the exhaust pipe 5.

In the above-described first, second and third embodiments and their modifications, the "steel sheet" bearing catalytic metal is disposed in the central region

of the exhaust pipe 5 or first catalytic-metal-bearing element 21, 51. More specifically, in the first embodiment of Figs. 1 to 9 and its modifications of Figs. 11A to 11H, the "steel sheet" bearing catalytic metal is embodied as the second catalytic-metal-bearing member 22 in the form of a hollow cylinder made of a porous steel sheet; in the embodiment of Figs. 12 and 13 and its modifications of Figs. 14 and 15, and in the examples of the embodiment of Figs. 16A and 16B, the "steel sheet" bearing catalytic metal is embodied as the second catalytic-metal-bearing member 52 in the form of a flat porous steel plate; and in the other examples of the third embodiment of Figs. 16C, 16D and 16E, the "steel sheet" bearing catalytic metal is embodied as the catalytic-metal-bearing members 66 and 69 in the form of a flat or corrugated porous plate, or porous semicylinder.

The "steel sheet" bearing catalytic metal should be understood as not being limited to the construction described above in relation to various embodiments and modifications and also as not being limited to the porous sheet. Also, the small openings in the porous sheet or plate may be of any desired shape, size and quantity.

#### INDUSTRIAL APPLICABILITY

As has been described so far, the exhaust purifying device for an internal combustion engine according to the present invention is characterized in that a steel sheet member having inner and outer catalytic-metal-bearing surfaces is disposed substantially in the central of an exhaust port extending from an exhaust port of the internal combustion engine. Thus, the catalytic metal is placed in the central region of the exhaust pipe where the temperature of the exhaust gas from the engine remains relatively high. The high-temperature exhaust gas effectively activates the catalytic metal on the steel sheet member, and this achieves the benefit that a sufficient exhaust purifying function of the catalytic metal can be acquired at low cost.

In one implementation, the steel sheet member is in the form of a hollow cylinder extending in the axial direction of the exhaust port, so that a pressure loss in the exhaust flowing through the steel sheet member can be reduced significantly to avoid adverse effects on the performance of the internal combustion engine.

Further, the cylinder is made of a porous steel sheet and closed at its upstream end. In this case, the exhaust gas is directed to pass through small openings formed through the wall thickness of the cylinder, during which time the exhaust gas contacts the catalytic metal on the inner and outer catalytic-metal-bearing surfaces. Thus, the exhaust is acted on by the catalytic metal in a greater area of the catalytic-metal-bearing surfaces and hence can provide an further enhanced exhaust purifying capability.

In another implementation, a hollow cylinder is provided and supported substantially in the central region of the exhaust pipe substantially along a center axis of



said pipe, and the hollow cylinder is made of a steel sheet having inner and outer catalytic-metal-bearing surfaces. Also, a partition plate is provided within the exhaust pipe to block passage of the exhaust gas between the cylinder and the exhaust pipe. Thus, the catalytic metal is placed in the central region of the exhaust pipe where the temperature of the exhaust gas from the engine remains relatively high, so that the high-temperature exhaust gas effectively activates the catalytic metal on the steel sheet member. This achieves the benefit that a sufficient exhaust purifying function of the catalytic metal can be acquired at low cost. In addition, the partition plate functions to restrict the pulsating motion of the exhaust gas caused by the engine, so as to provide a generally smooth steady flow of the exhaust gas. Owing to the provision of such a partition plate, the purifying capability of the exhaust purifying apparatus does not significantly vary and can achieve sufficient exhaust purification. Further, because the steel cylinder is supported via the partition plate restricting the pulsating motion of the exhaust gas, no separate support is required, which simplifies the supporting mechanism for the cylinder.

Besides, the steel cylinder is mounted in such a manner that the cylinder is free to axially expand and contract relative to the exhaust pipe, and this feature easily accommodates a difference in axial thermal expansion between the steel cylinder and exhaust pipe.

In still another implementation, a first catalytic-metal-bearing member is provided within the exhaust pipe along an inner wall surface of said pipe and a second catalytic-metal-bearing member is provided substantially in the central of the first catalytic-metal-bearing member. Thus, the catalytic-metal-bearing members are provided near the inner wall surface of and in the central region of the exhaust pipe, and the exhaust purifying function can be further enhanced without adversely affecting the performance of the internal combustion engine and yet at low cost.

#### Claims

1. An exhaust purifying apparatus for an internal combustion engine (3) comprising an exhaust pipe (5) extending from an exhaust port (4) of the internal combustion engine (3) for purifying exhaust gas from the engine (3), characterized in that a steel sheet member (22) bearing catalytic metal is provided substantially in a central region of said exhaust pipe (5).
2. An exhaust purifying apparatus as claimed in claim 1 wherein said steel sheet member (22) is a hollow cylinder extending in an axial direction of said exhaust port (5).
3. An exhaust purifying apparatus as claimed in claim 1 wherein said hollow cylinder is made of a porous

steel sheet and closed at an upstream end thereof.

4. An exhaust purifying apparatus for an internal combustion engine (3) comprising an exhaust pipe (5) extending from an exhaust port (4) of the internal combustion engine (3) for purifying exhaust gas from the engine (3), characterized in that a hollow cylinder (22) is provided and supported substantially in a central region of said exhaust pipe (5), said hollow cylinder (22) being made of a steel sheet (22) bearing catalytic metal, and that a partition plate (27) is provided within said exhaust pipe (5) to block passage of the exhaust gas between said cylinder (22) and said exhaust pipe (5).
5. An exhaust purifying apparatus as claimed in claim 4 wherein said hollow cylinder (22) is mounted in such a manner that said cylinder (22) is free to expand or contract axially relative to said exhaust pipe (5).
6. An exhaust purifying apparatus for an internal combustion engine (3) comprising an exhaust pipe (5) extending from an exhaust port (4) of the internal combustion engine (3) for purifying exhaust gas from the engine (3), characterized in that a first catalytic-metal-bearing member (21; 51) is provided substantially in a central region of said exhaust pipe (5) and a second catalytic-metal-bearing member (22; 52) is provided substantially in a central region of said first catalytic-metal-bearing member (21; 51).
7. An exhaust purifying apparatus as claimed in claim 6 wherein said first catalytic-metal-bearing member (51) is in the form of a cylinder and said second catalytic-metal-bearing member (52) is a flat plate.
8. An exhaust purifying apparatus as claimed in claim 6 wherein each of said first catalytic-metal-bearing member (21; 51) and second catalytic-metal-bearing member (22; 52) has a multiplicity of openings (21a, 22c; 51c, 52a) formed through a wall thickness thereof.

FIG. 1

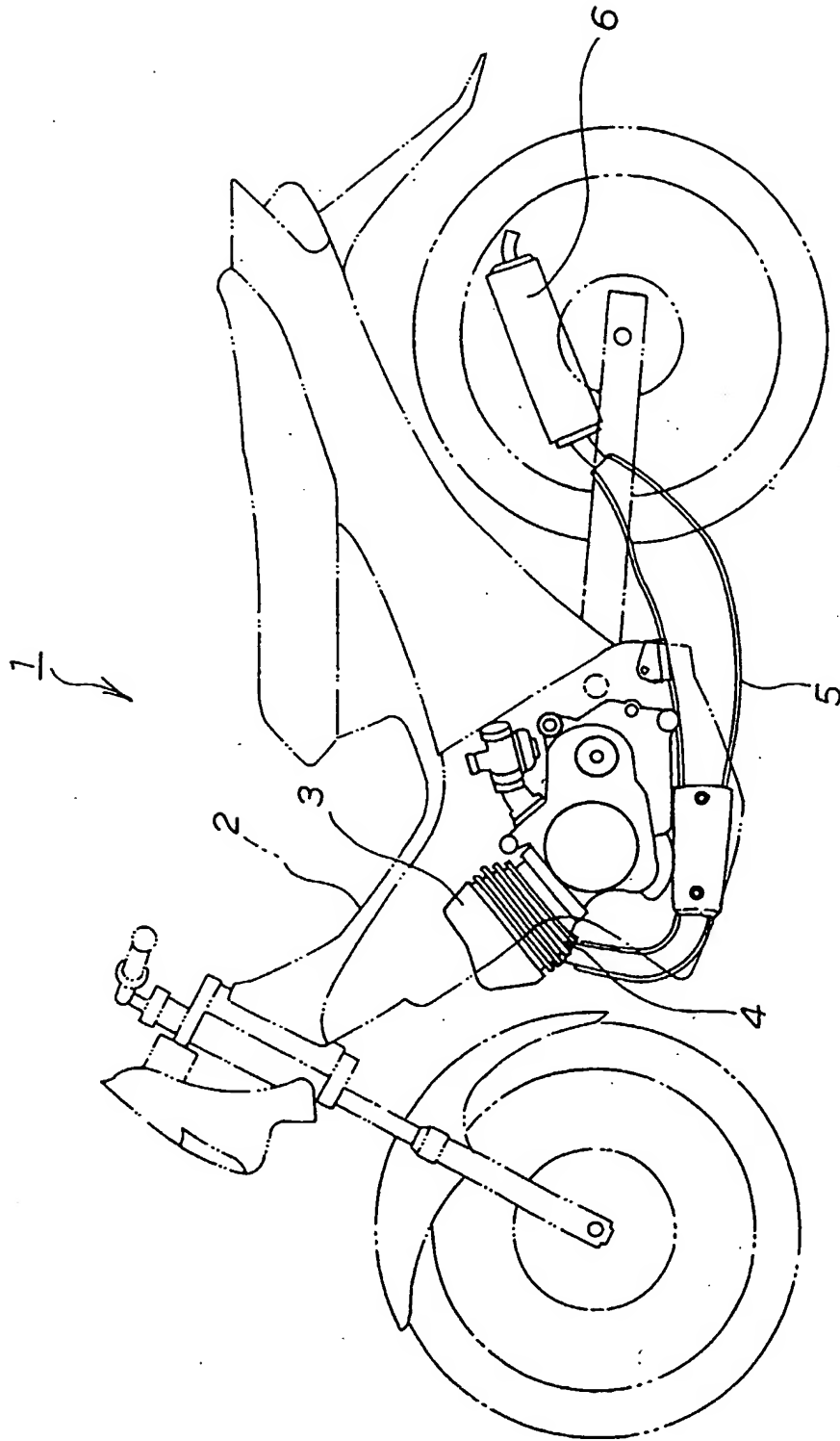


FIG. 2

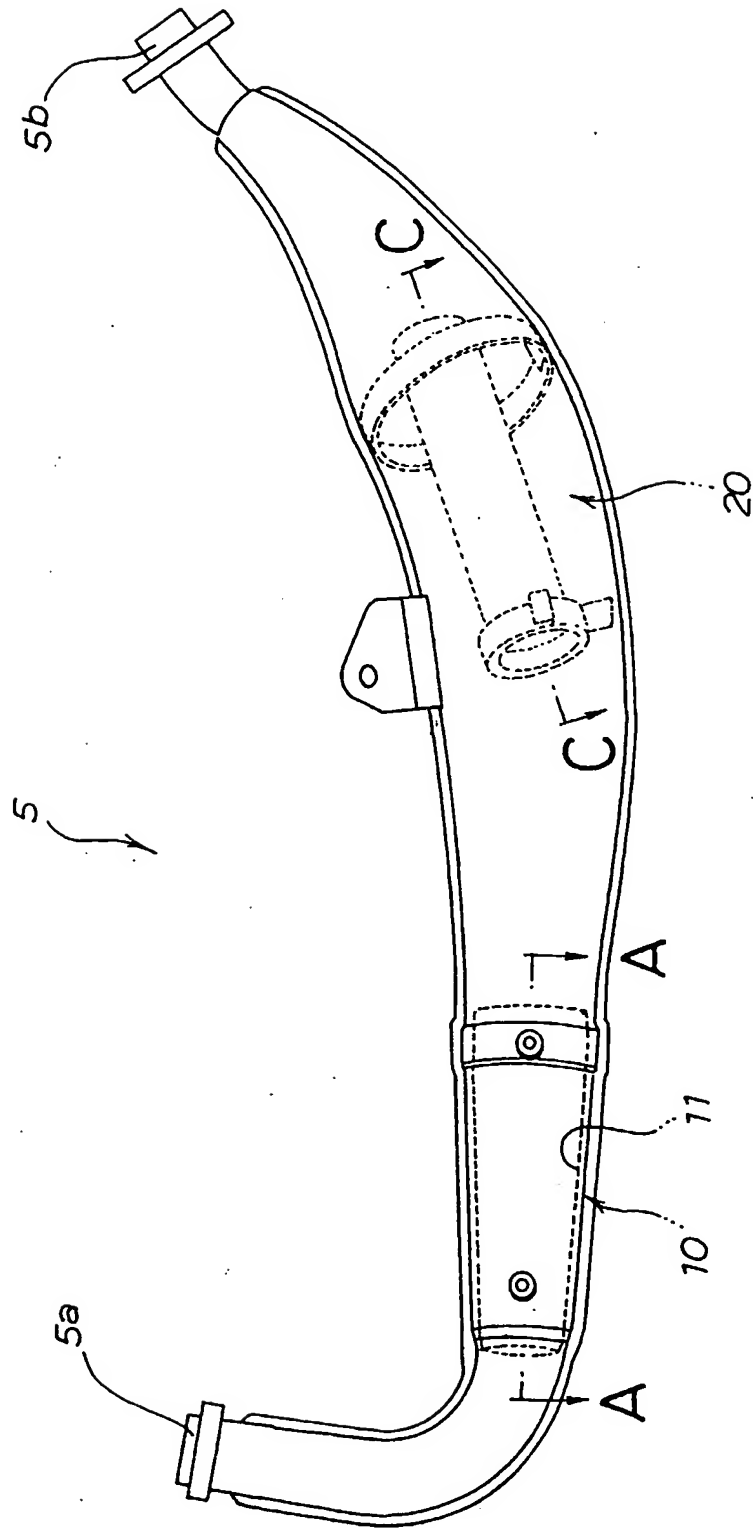


FIG. 3

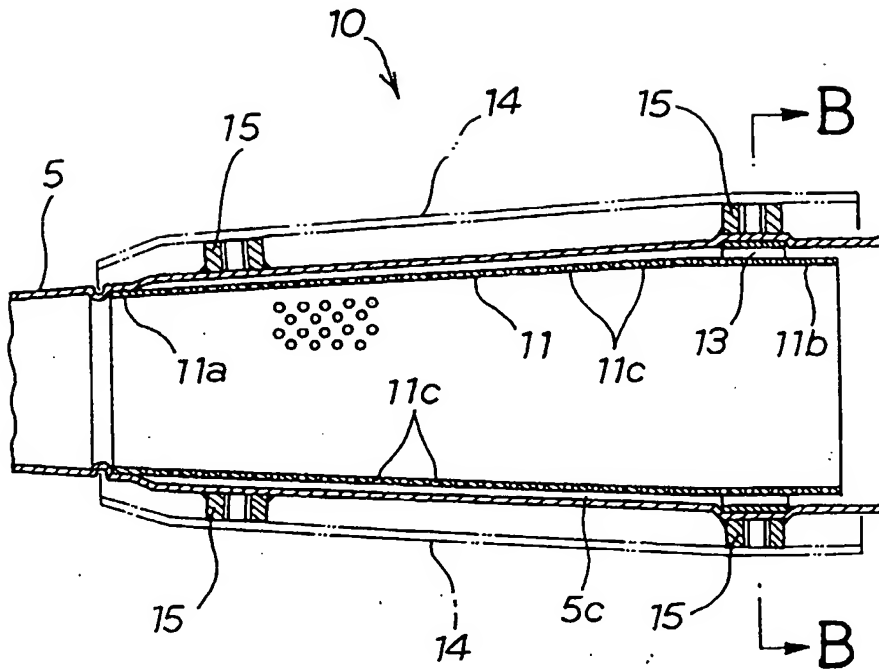


FIG. 4

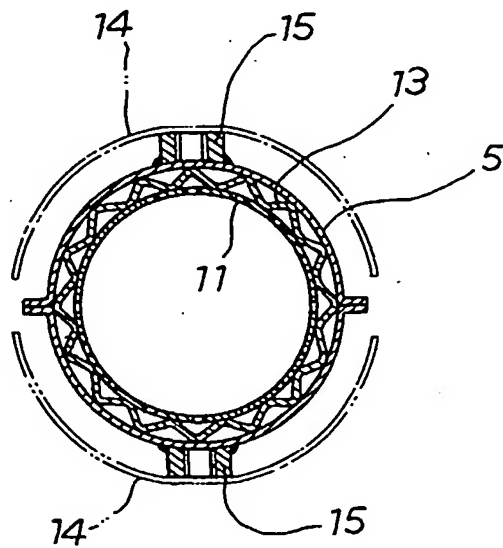


FIG. 5

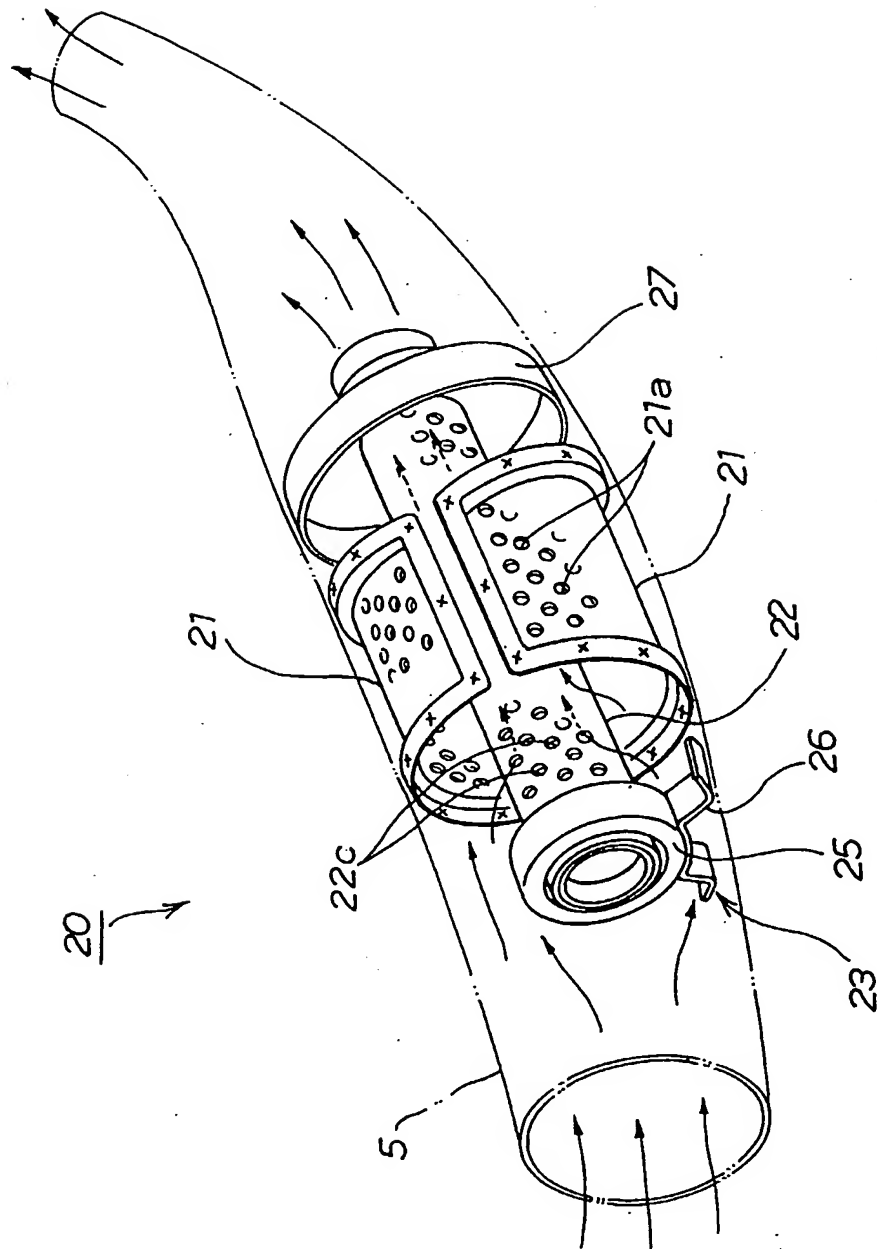


Fig. 6

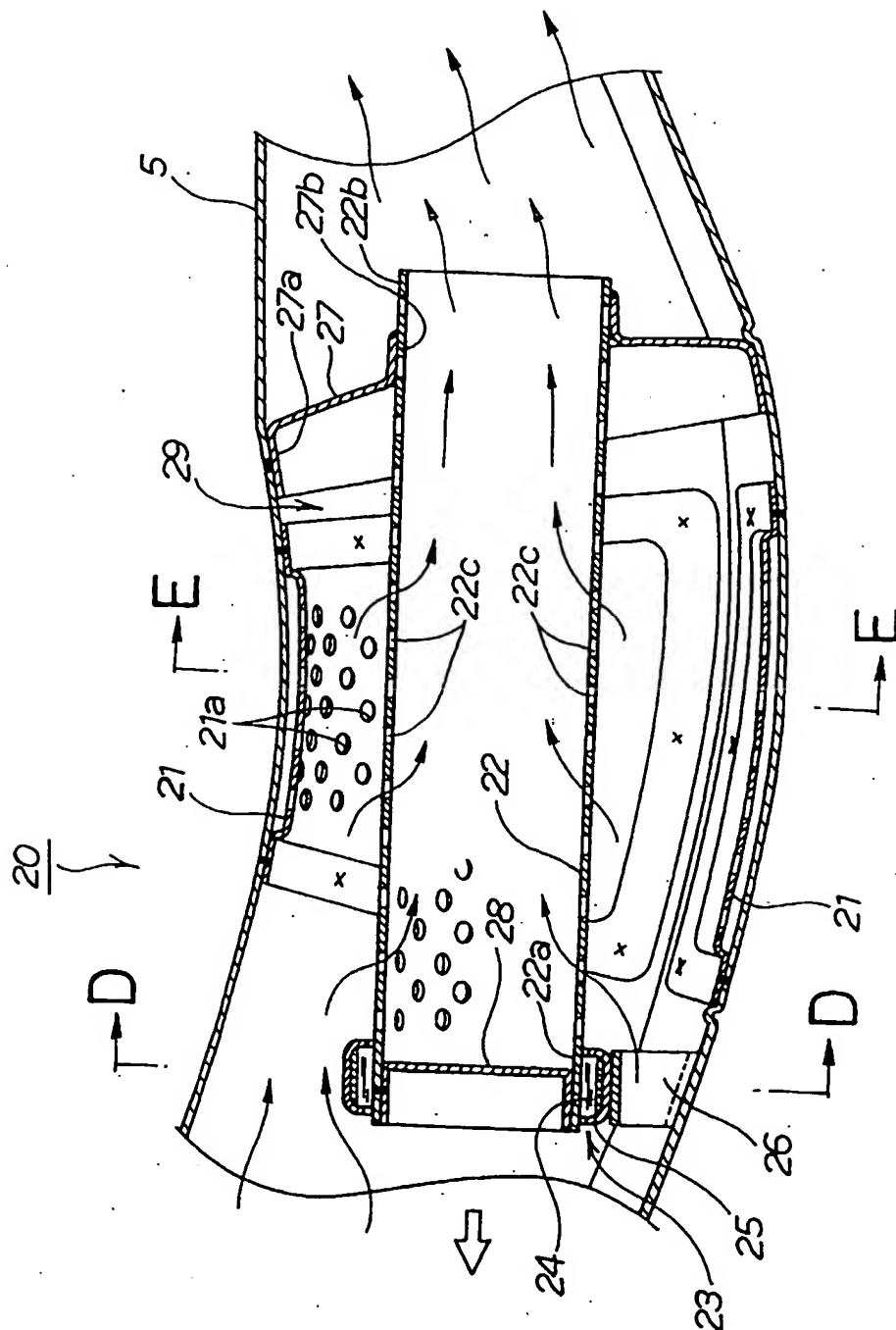




FIG. 7

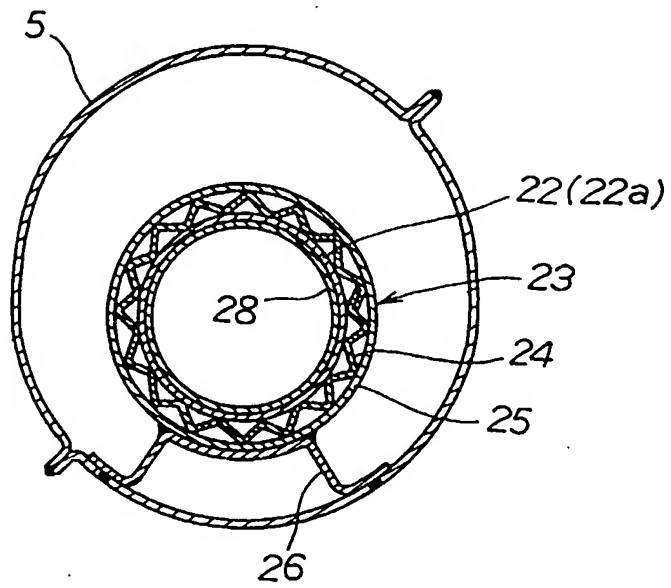


FIG. 8

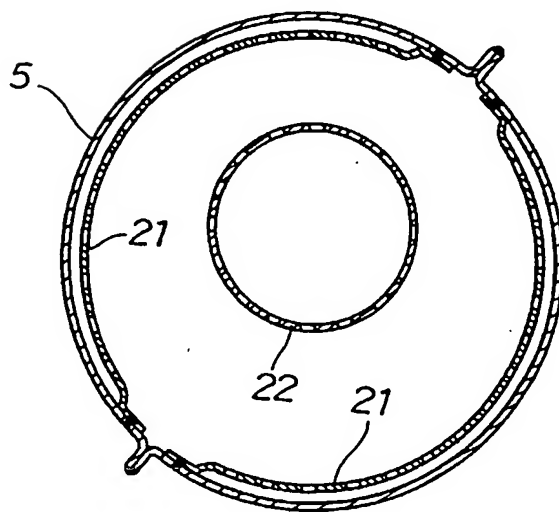


FIG. 9A

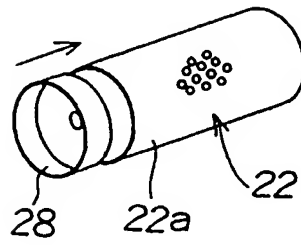


FIG. 9B

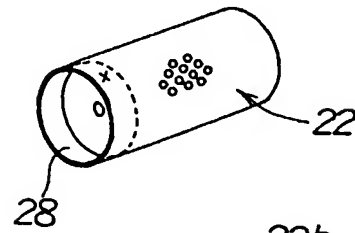


FIG. 9C

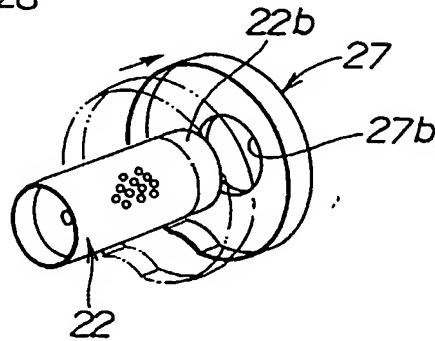


FIG. 9D

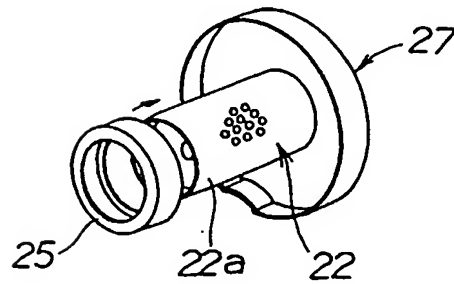


FIG. 9E

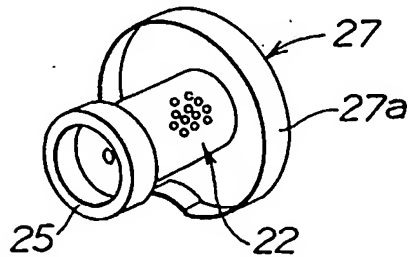


FIG. 10A

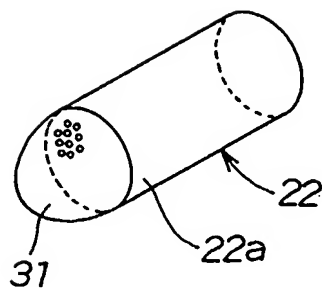


FIG. 10B

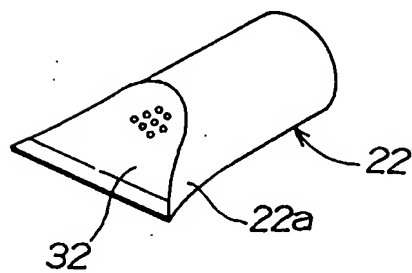


FIG. 10C

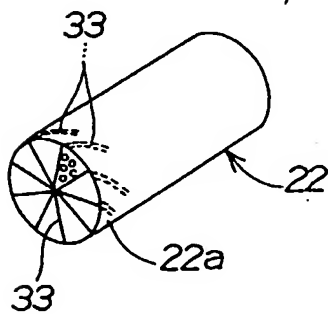


FIG. 10D

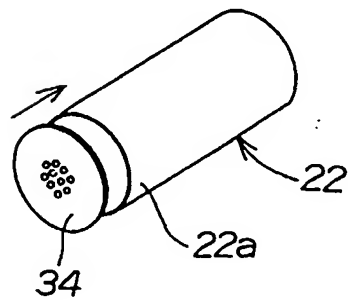


FIG. 11A

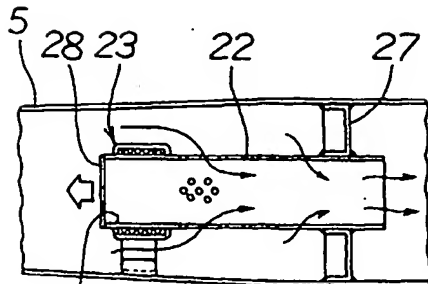
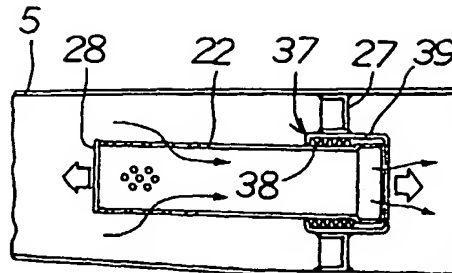


FIG. 11E



22a FIG. 11B

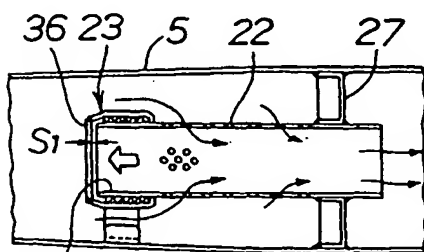


FIG. 11F

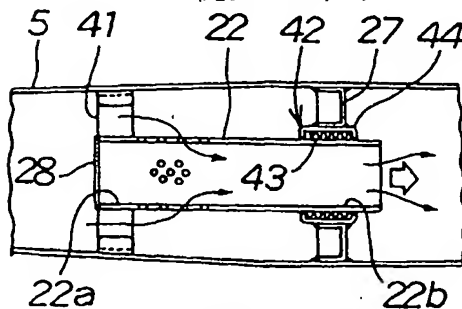


FIG. 11C

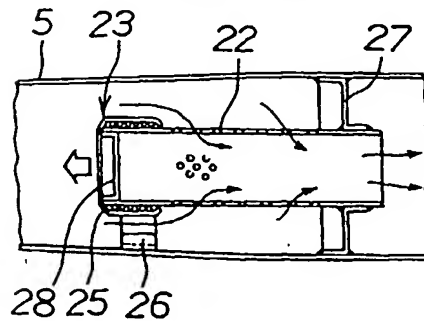


FIG. 11G

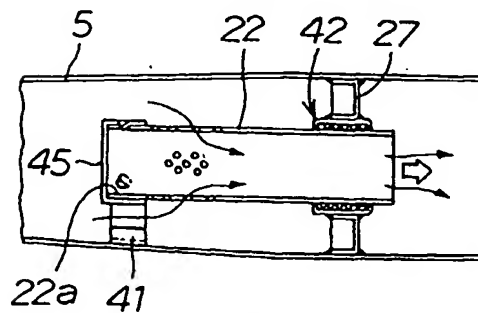


FIG. 11D

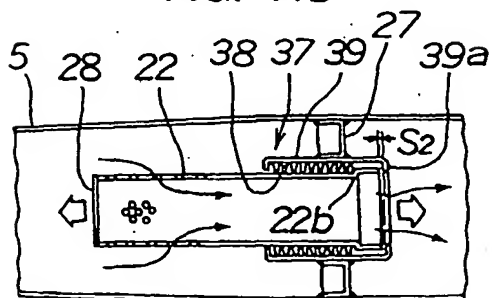


FIG. 11H

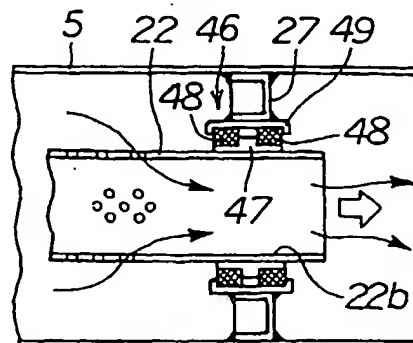


FIG. 12

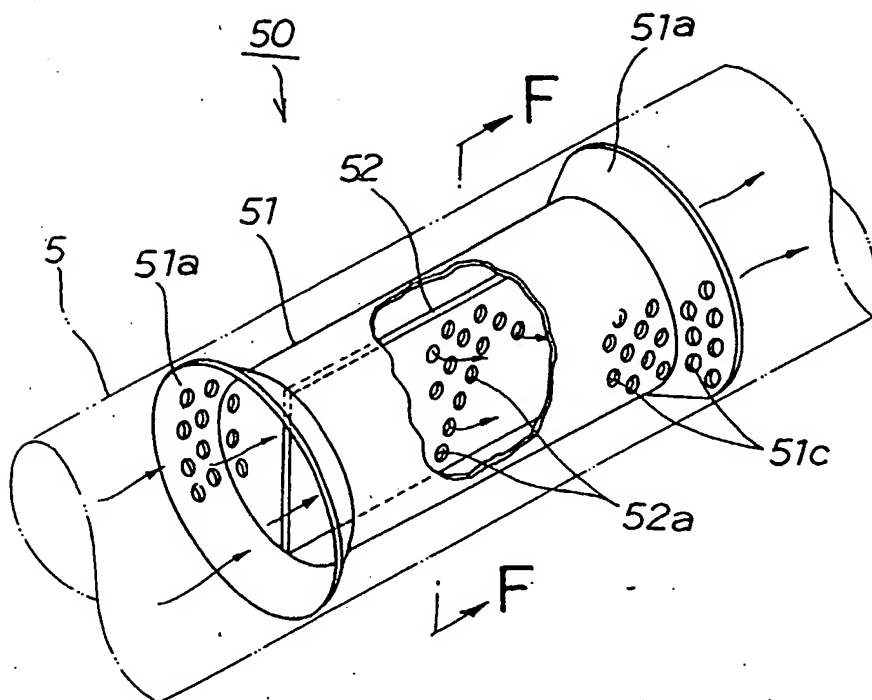


FIG. 13

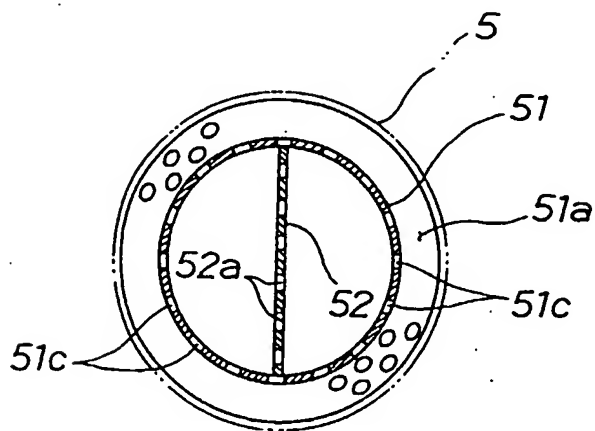


FIG. 14

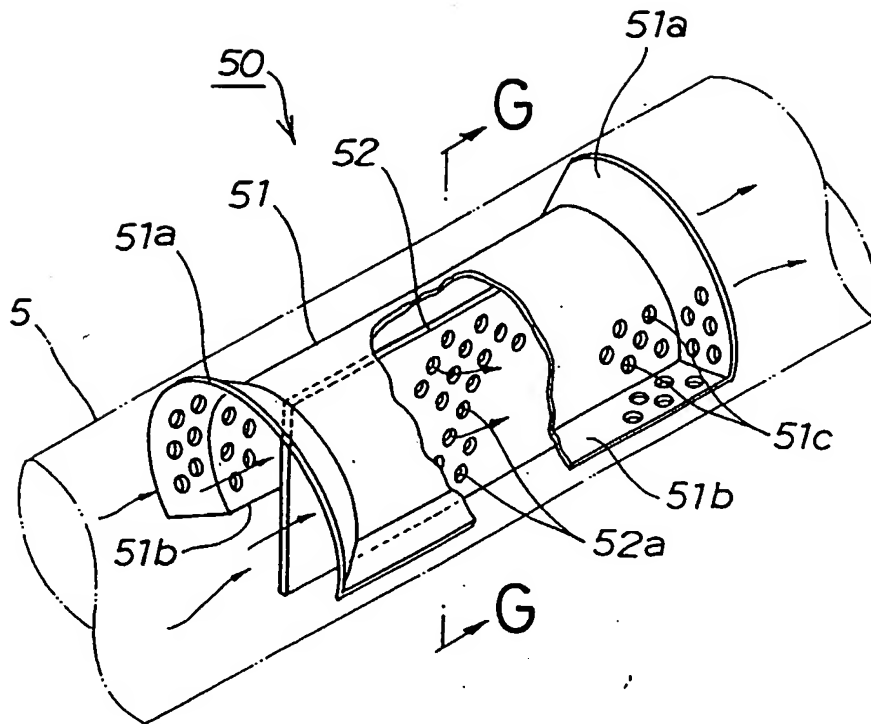


FIG. 15

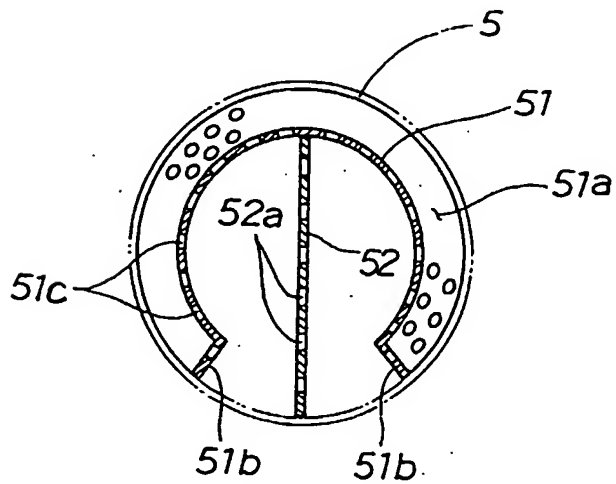




FIG. 16A

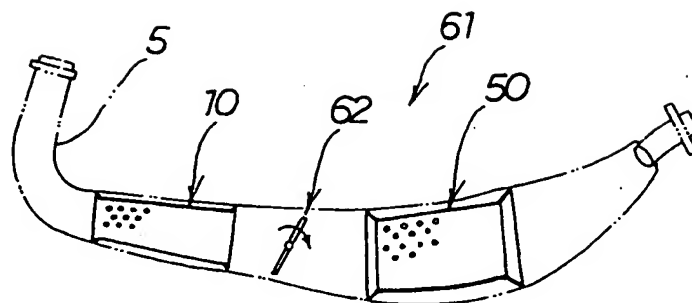


FIG. 16B

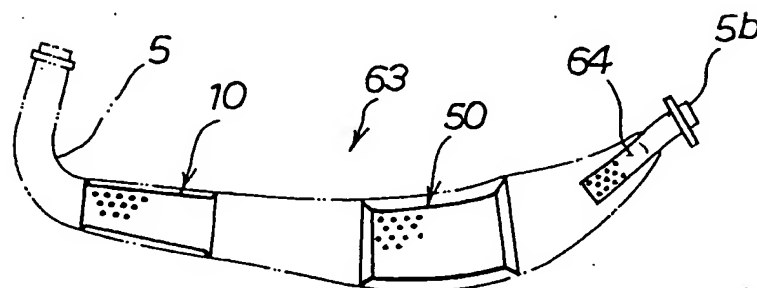


FIG. 16C

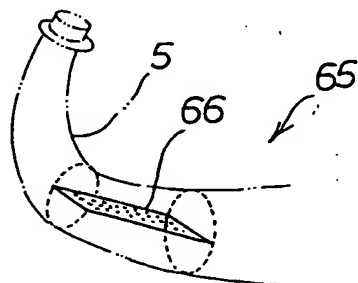


FIG. 16D

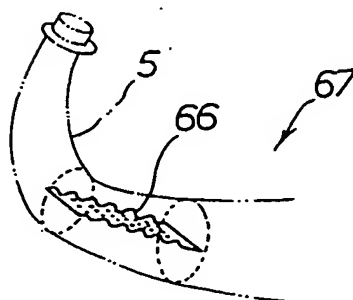


FIG. 16E

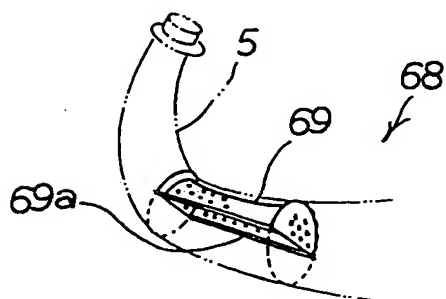


FIG. 17

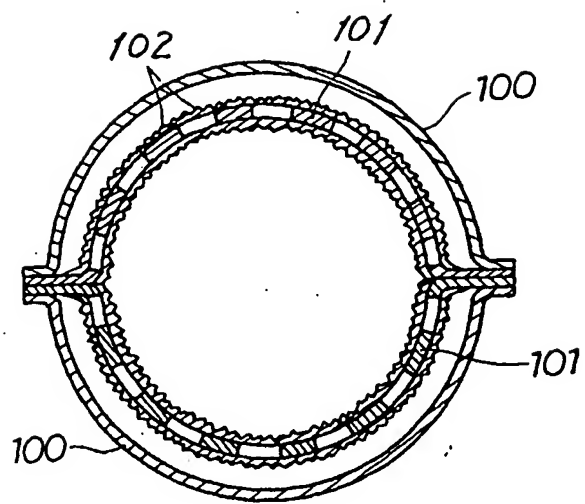


FIG. 18

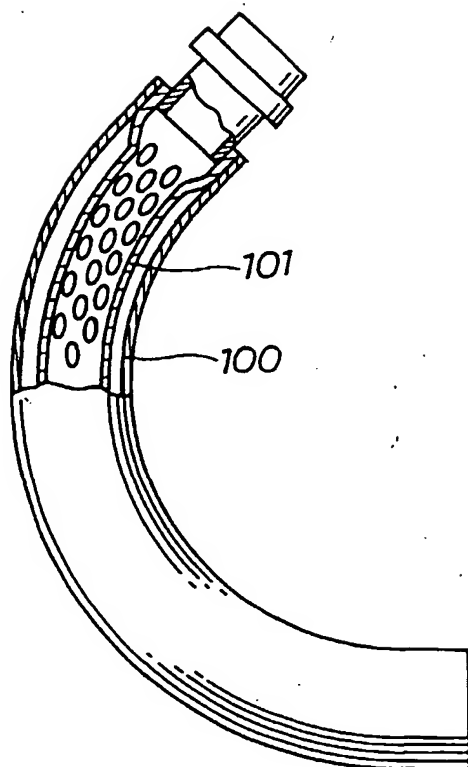


FIG. 19

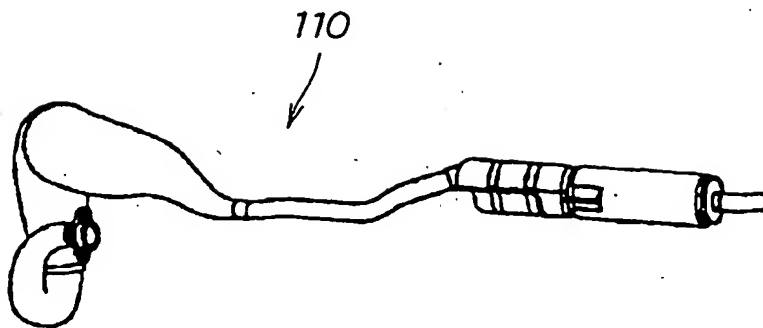


FIG. 20

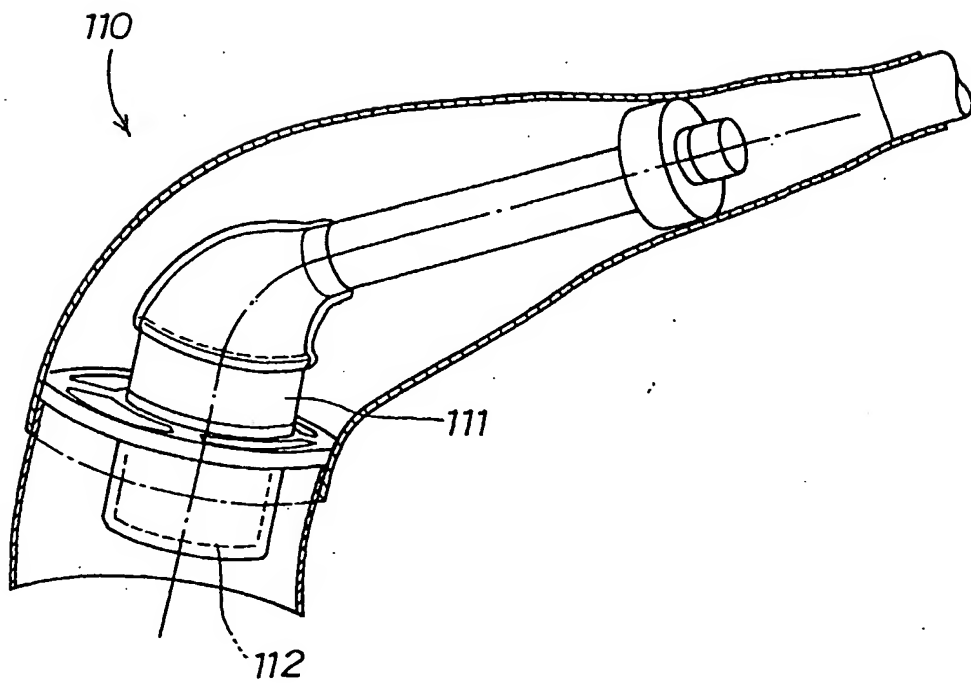
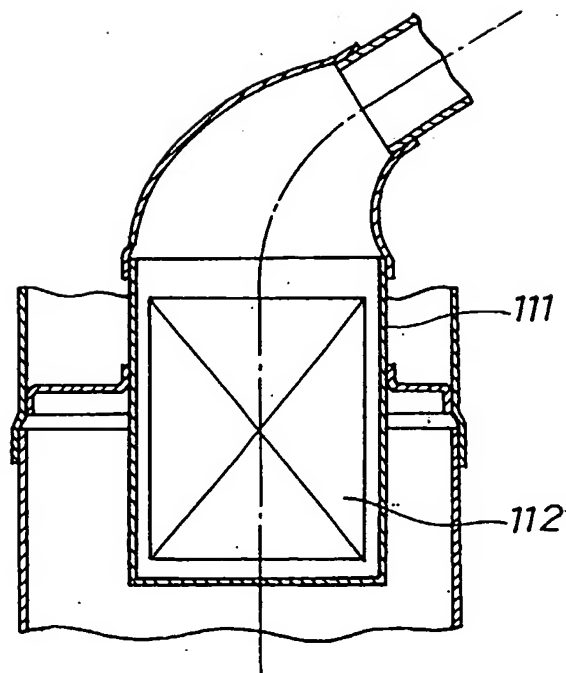


FIG. 21





## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP96/01382

## A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl<sup>6</sup> F01N3/24, F01N3/20

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl<sup>6</sup> F01N3/24, F01N3/20, F01N3/28

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1926 - 1996

Kokai Jitsuyo Shinan Koho 1971 - 1996

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP, 3-85320, A (Suzuki Motor Corp.), April 10, 1991 (10. 04. 91), Page 2, upper right column, line 17 to lower left column, line 14 & EP, A1, 415356	1, 2
X	JP, 4-334717, A (Suzuki Motor Corp.), November 20, 1992 (20. 11. 92), Column 2, lines 7 to 21 (Family: none)	1, 2
A	JP, 62-160726, U (Nippon Radiator K.K.), October 13, 1987 (13. 10. 87) (Family: none)	3, 4
A	JP, 51-131517, U (Daihatsu Motor Co., Ltd.), April 15, 1975 (15. 04. 75) (Family: none)	3, 4
A	JP, 63-83417, U (Nippon Radiator K.K.), June 1, 1988 (01. 06. 88), Page 6, line 20 to page 7, line 7 (Family: none)	5
X	JP, 7-54642, A (Suzuki Motor Corp.),	6 - 8

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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"A" document member of the same patent family

Date of the actual completion of the international search  
August 20, 1996 (20. 08. 96)Date of mailing of the international search report  
September 3, 1996 (03. 09. 96)Name and mailing address of the ISA/  
Japanese Patent Office

Authorized officer

Facsimile No.

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP96/01382

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	February 28, 1995 (28. 02. 95), Column 2, lines 19 to 25 (Family: none)	

Form PCT/ISA/210 (continuation of second sheet) (July 1992)